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(71) Applicant
N V Philips' Gloeilampenfabrieken
Pieter Zeemanstraat 6
NL-5621 CT Eindhoven
The Netherlands
(72) Inventor
Wolfgang Wagner
(74) Agents
R J Boxall
Mullard House
Torrington Place
London WC1E 7HD

(54) Radiation absorption distribution measurement in a part section of a body

(57) If the absorption distribution in only a part, for example a separate organ, of a body section under examination is required, the overall radiation dose administered to the body can be reduced. The part region 11 is irradiated with the full intensity by a beam limited 11a 11b to the width of the region 11 during a first measurement cycle. In order to avoid reconstruction errors, the entire body slice 6 is irradiated during a second measurement cycle by a beam 9, 10 having a second intensity which is substantially lower than the first intensity. Thus, along each measurement path through the part region 11 of the body section 6 there are available two absorption values from which suitable correction factors can be determined for correcting all the absorption values measured with the second intensity and lying outside the region 11 so that errors with respect to the absorption values measured using the first intensity, can be corrected to reduce artefacts during the reconstruction.

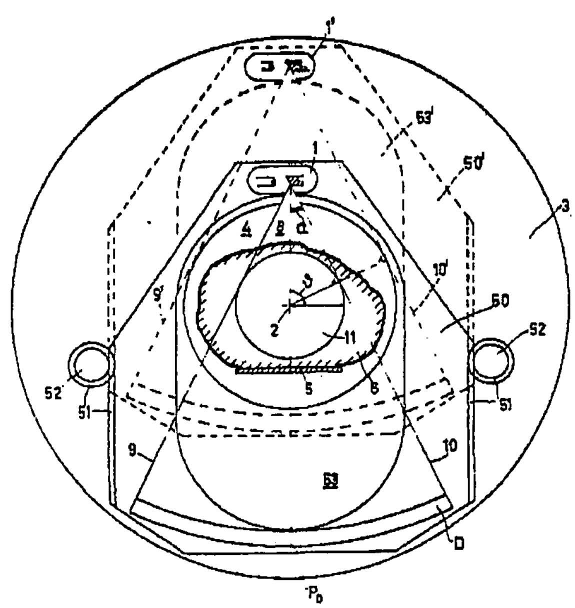

FIG.1a

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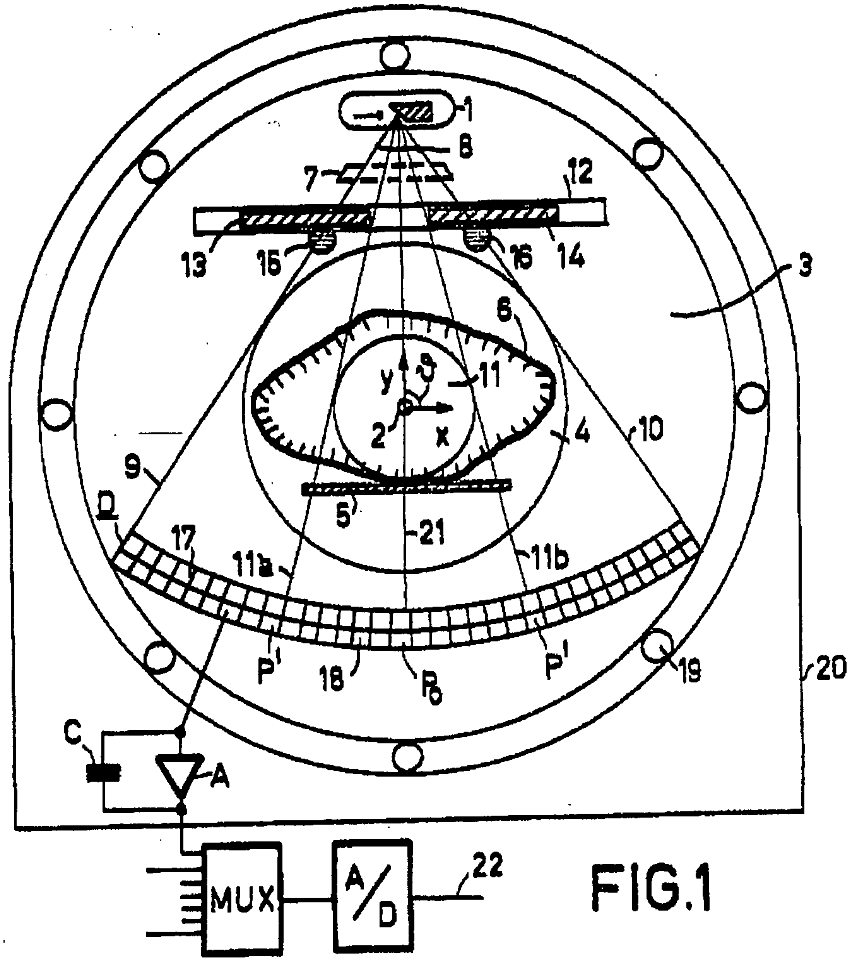
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FIG.1

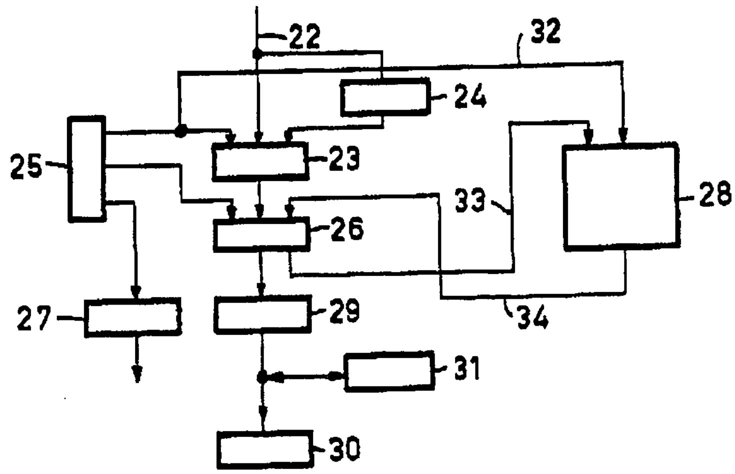
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FIG.2

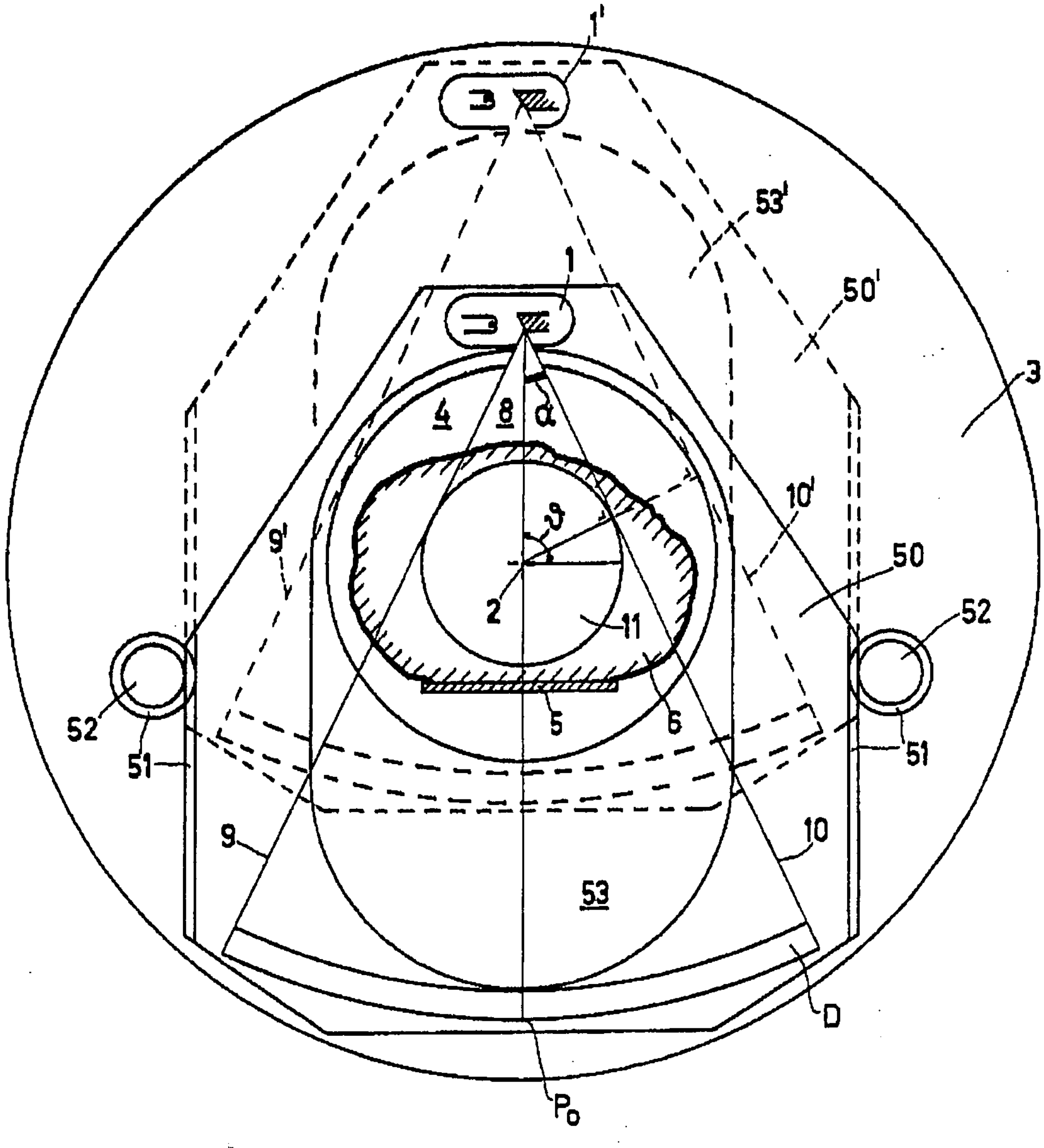

FIG.1a

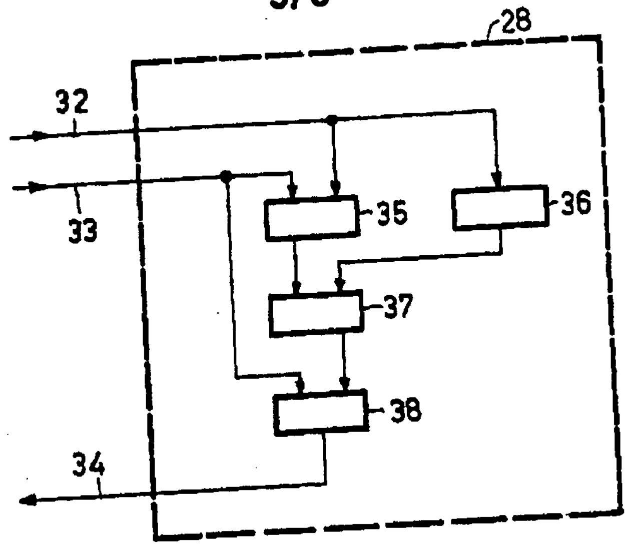

FIG.3

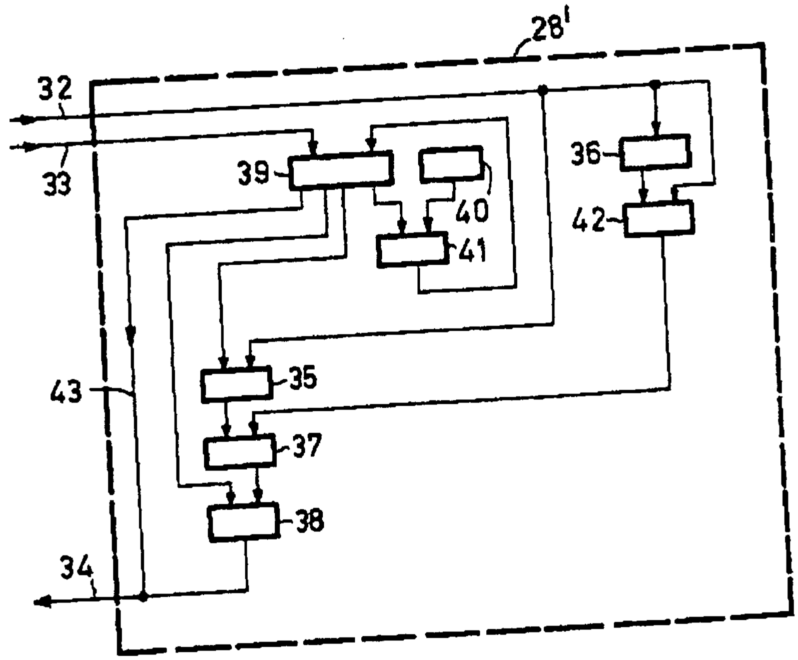

FIG.4

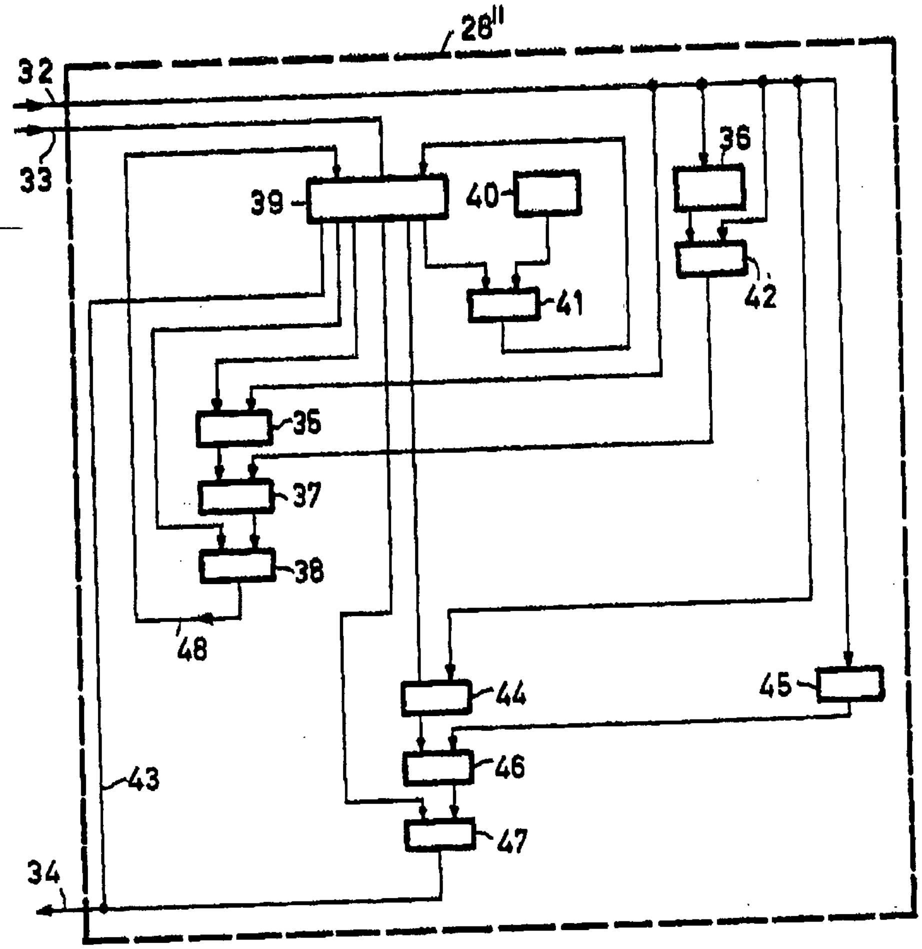

FIG.5

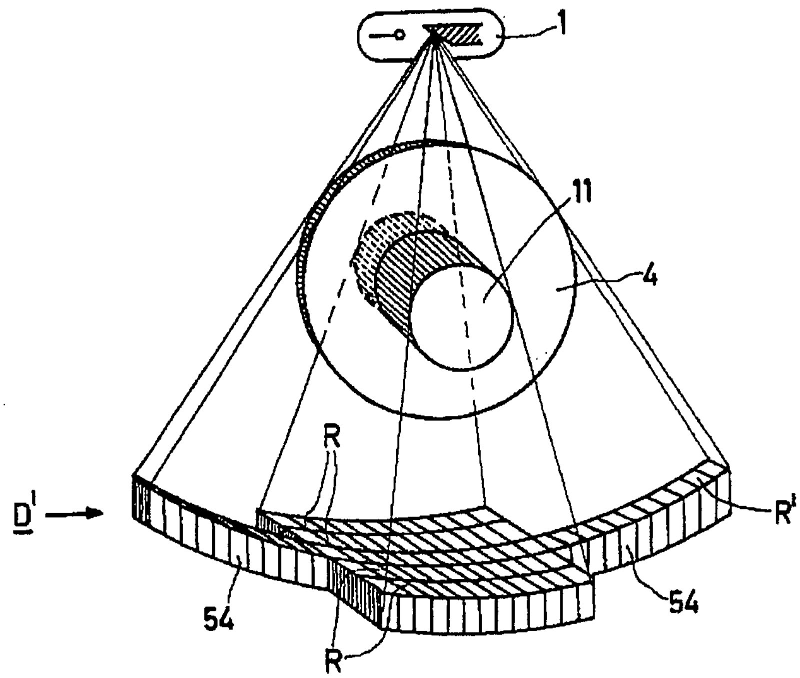

FIG.6a

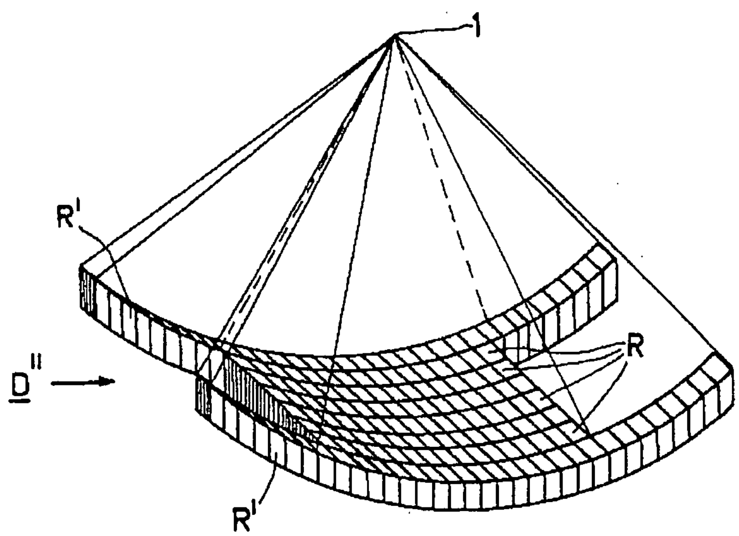

FIG.6b

SPECIFICATION

Method of and device for determining the distribution of radiation absorption in a planar section of a body

The invention relates to a method of determining the distribution of radiation absorption in a flat examination zone in a body which is situated within a positioning zone which completely encloses the examination zone, the examination zone beng completely irradiated in different measuring directions which are situated within the examination zone along a large number of measuring paths by means of radiation of a first intensity in order to determine first measurement values, the part of the positioning zone which is situated outside the examination zone being irradiated in a corresponding number of measuring directions along measuring paths by means of radiation of a second intensity which is lower than the first intensity in order to determine second measurement values, first absorption values being determined from the first measurement values and second absorption values being determined from the second measurement values, said absorption values being used for the reconstruction of the distribution of radiation absorption.

A method and a device of this kind are already known from Canadian Patent Specification No. 1,072,688. Therein, a fan-shaped radiation beam emitted by a radiation source is limited by means of a diaphragm device so that the radiation beam irradiates only the width of the examination zone, corresponding to a zone in the body section to be reconstructed, with an unattenuated intensity for the determination of the absorption values. The radiation of the radiation beam which extends outside the examination zone is strongly but not completely absorbed by the diaphragm device, so that outside the zone the body section is irradiated with a substantially lower intensity. Because the measurement values of the radiation extending outside the examination zone contain a comparatively large amount of noise, radiation absorption coefficients can be derived therefrom only with a limited accuracy.

A method of this kind for the determination of the absorption distribution is suitable for significantly reducing the radiation dose to which a body is exposed, for example, if a given part of the body, for example an individual organ of a human body, which is situated within the body slice, has to be examined. In order to avoid large reconstruction errors in the examination zone if the overall section of the body is greater than the examination zone, it is necessary to determine not only measurement values associated with measurement paths through the examination zone, but also measurement values associated with measurement paths extending outside the examination zone (see W. Wagner, "Reconstruction from truncated scan data", published in Mediata, special issue 1/78).

However, due to the presence of the diaphragm device, the radiation extending outside the examination zone will have a mean radiation energy which is greater than that of radiation passing directly through the examination zone ("radiation hardening"). The corrections of the absorption values which are necessary as a result of the different mean radiation energies, in order to obtain a correct reconstruction of the absorption distribution, however, necessitate complex arithmetic operations and consequently a comparatively long calculation time.

Moreover, when employing the previously described method, a part of the scattered radiation produced in the examination zone will be measured by detectors which are intended to measure the radiation of reduced intensity which extends outside the examination zone, and this will cause inaccurate second measurement values.

The invention has for an object to provide a method of and a device for determining the distribution of radiation absorption in a planar section of a body wherein the amount of radiation to which the body is exposed can be substantially reduced while reducing or removing the need for difficult corrections of the measurement values due to different mean radiation energies and correction for scattered radiation.

A method in accordance with the invention is characterized in that during a first measuring cycle the examination zone of the body slice to be examined is irradiated with the first intensity in order to determine the first measurement values, whilst during a second measuring cycle the total positioning zone of the same or a neighbouring body slice is irradiated with the second intensity in order to determine second measurement values.

Herein, a measurement cycle is to be understood to mean the successive irradiation of a body section along all measurement directions situated in the slice by means of a plurality of measurement beams for respectively deriving either the first or the second group of measurement values, both of which are required for the reconstruction of a distribution of the radiation absorption. Such a radiation beam may be fan-shaped. The measurement values obtained may be selected to form sets of measurement values so that the measurement paths associated with a group of measurement values extend in parallel. The term first and second measurement cycles is no to be taken to imply any sequence in time whatsoever. The second measurement cycle may directly follow the first cycle, but may equally well have been performed earlier.

Simultaneous execution of the two measurement cycles, however, must not take place.

Tests have revealed that for the determination of the absorption distribution within the examination zone it suffices that the second measurement values along measurement paths extending outside the examination zone are at least approximately known. This means that less severe requirements may be imposed as regards the absence of noise and the accuracy of the second measurement values than on the measurement values determined along measurement paths extending through the examination zone, so that the determination of second measurement values outside the examination zone may be performed with a substantially lower radiation intensity. The second measurement values may also be measured in a further body section adjacent the body section.

When the mean radiation energies of the radiation during the first and the second measurement cycle are at least approximately the same, first and second absorption values which correspond to the integral of the radiation absorption in the body along the relevant measurement paths can be determined from the measurement values obtained, so that the absorption values need not be corrected for the different mean radiation energies.

In a further embodiment in accordance with the invention, the body is displaced in a direction transversely of all measuring directions in order to irradiate at least one second body slice which adjoins a first already irradiated body slice, after which only an examination zone in the second body slice to be examined is irradiated with radiation of the first intensity in order to determine first absorption values, the second absorption values of the first irradiated body slice whose associated measuring paths extend outside the examination zone being used for each measuring direction as approximated second absorption values for the reconstruction of the radiation absorption distribution in the second body slice.

This is because it is often necessary to determine the internal structure of a body in a three-dimensional zone. This is usually achieved by the reconstruction of the absorption distribution in different, adjoining parallel body sections. If the examination zones in the various body sections are at least approximately equally large and occupy approximately the same position in the examination plane, it is merely necessary to irradiate only one body section, for example, the first body section, in order to record first and second measurement values. For all other body sections, only the examination zone is irradiated with radiation of a first intensity in order to determine first measurement values or first absorption values; this results in an important reduction of the radiation dose to which the body is exposed or in a substantial reduction of the time required for determining a sufficient number of measurement values for the reconstruction of the absorption distribution of the irradiated body slices.

In a further preferred embodiment in accordance with the invention, the second intensity which is lower than the first intensity is adjusted by reduction of the tube current of an X-ray source, so that the radiation energy spectrum of the X-ray tube remains the same, with the result that no correction of the absorption values due to different mean radiation energies in the successive first and second measuring cycles is necessary.

Between the first and the second absorption values disturbing deviations ofter occur *inter alia* due to: movement of the patient, drift in the radiation spectrum of the radiation source and, in the case of irradiation of several adjacent body slices, also due to structures in the body. Therefore, the second measurement values are also determined along measuring paths through the examination zone. From the first and the second measurement values first and second absorption values, respectively, are then determined in the manner to be described hereinafter.

According to a further version of the method in accordance with the invention, for each measuring direction there is formed a correction factor whereby the second absorption values whose associated measuring paths extend outside the examination zone are multiplied in order to form approximated second absorption values, the correction factor being determined by dividing all first absorption values which are associated with one measuring direction and with measuring paths extending through the examination zone by the second absorption value associated with the same measuring path, after which all quotients are arithmetically averaged in order to determine the correction factor.

A measuring path extending through the examination zone has associated with it two absorption values whereby a suitable correction factor is determined for reducing the said deviations so that the second absorption value along a measuring path through the examination zone exhibits no deviations or only small deviations with respect to the first absorption values along the same measuring path. A correction factor is then calculated for each measuring direction.

Tests have demonstrated that the correction factors which lead to a high degree of correspondence between the first and the second absorption values within the examination zone can be used for determining approximated second absorption values whose associated measuring paths extend outside the examination zone. The second absorption values determined outside the examination zone are then multiplied by an associated correction factor.

A preferred version of a method in accordance with the invention is characterized in that

during the first and the second measuring cycle a source for generating the penetrating radiation is situated at a first and a second distance, respectively, from the examination zone, the first distance being smaller than the second distance.

Embodiments in accordance with the invention will now be described by way of example, with reference to the accompanying diagrammatic drawing, of which:—

Figure 1 shows an X-ray tomography apparatus for measuring first and second measurement values in accordance with the invention, comprising a displaceable diaphragm device,

Figure 1a shows a preferred embodiment of an X-ray tomography apparatus for measuring first and second measurement values,

Figures 2, 3, 4 and 5 show different block diagrams for the processing of the measurement values determined in accordance with the invention, and

Figures 6a, b show embodiments of detector devices comprising more than one row of detectors.

Fig. 1 diagrammatically shows a computed tomography apparatus which comprises a radiation source 1, for example, an X-ray tube, which is arranged on a support 3 which is rotatable about a system axis 2 which extends perpendicularly to the plane of the drawing. The support 3 may be, for example, a flat plate which is provided with an opening which is concentric with the system axis 2 and which determines the size and the position of a positioning zone 4 for a body 6 arranged on a patient table 5. The radiation emitted by the radiation source 1 is limited by means of a first diaphragm 7 so that a fan-shaped, flat radiation beam 8 is obtained whose extreme rays 9 and 10 are tangential to the positioning zone 4. In otder to reduce the angle of spread of the radiation beam 8 or for limiting the radiation beam 8 to an examination zone 11 which is preferably concentric with the system axis 2, there is provided a further diaphragm device 12 which comprises absorption pieces 13, 14 which completely absorb the radiation of the radiation beam 8 and which are arranged to be displaceable by means of drive wheels 15, 16. The intensity of the radiation emitted by the radiation source 1 is measured by means of a row of detectors D which comprises separate radiation detectors 18 which are provided with collimators 17. Each radiation detector 18 is formed, for example, by an ionization chamber and is connected to an integrating amplifier A, C. *Via* a multiplex circuit MUX, to which further amplifiers of the other detectors 18 are also connected, the integrated measurement signal is periodically sampled and is applied, *via* an analog-to-digital converter A/D, and a connection 22, to a processing circuit yet to be described. The measuring rays 11a and 11b which are tangential to the examination zone 11 are incident on the radiation detectors 18 whose positions within the row of detectors D are denoted by the reference p'. p' is, for example, the number of the twelfth radiation detector, taken from the radiation detector which occupies the central position P_0 and on which the central ray 21 of the radiaton beam 8 impinges. Therefore, if the width of all radiation detectors 18 is the same, the number p' is a measure of the distance between the radiation detector associated with a position p and the radiation detector occupying the position p_0.

The two diaphragm devices 7 and 12 and the row of detectors D are mounted on the support 3 which itself is rotatably journalled in a frame 20 by means of suitable bearings 19. If the centre of the examination zone 11 is not situated on the system axis 2, the position of the absorption pieces 13, 14 of the diaphragm device 12 is changed so that the central rays 11a, b are tangential to the examination zone 11 in any rotary position of the support 3. The position and the size of the examination zone 11 are then suitably adjusted prior to the irradiation of the body 6 or the body slice. The described adjustment of the diaphragms is known *per se* from Canadian Patent No. 1,072,688. Hereinafter it is assumed that the centre of the examination zone 1 coincides with the system axis 2.

For the determination of a radiation absorption distribution in a slice of the body 6, the body is irradiated in two measurement cycles. During one measurement cycle, the support 3 is rotated for example through 360°, while the body 6 or the examination zone 11 is successively irradiated in, for example, 600 different measurement directions, denoted by the angle ϑ which is enclosed by the central ray 21 of the fan-shaped radiation beam 8 and the x-axis of a rectangular coordinate system $\{x, y\}$ which is stationary relative to, and situated in the slice. The origin of the coordinate system $\{x, y\}$ is situated on the system axis 2. The separate radiation detectors 18 supply measurement values $I(p, \vartheta)$ which are dependent on the angle ϑ and on the position p of an individual radiation detector 18 in the detector row D.

During a first measurement cycle, the absorption pieces 13, 14 limit the fan-shaped radiation beam 8 to the width of the preselected examination zone 11 which is irradiated with radiation of a first (primary) intensity I_{01} in order to measure first measurement values $I_1(p,\vartheta)$ which are allocated to a first group. Radiation which would otherwise extend along measurement paths outside the examination zone 11 is, therefore, completely absorbed.

During a second measurement cycle, the absorption pieces 13, 14 are moved entirely out of the path of the radiation beam 8, so that the entire positioning zone 4 (and hence the whole of the body slice) is irradiated with a second intensity I_{02} which is substantially less, for example,

more than ten times less, than the first intensity I_{01} in order to measure second measurement values $I_2(p,\vartheta)$ which are allocated to a second group of measurement values. The intensity variation is realized, for example, by reducing the tube voltage of the X-ray tube or the radiation source 1, so that radiation having a different mean radiation energy is generated. The variation of the intensity of the radiation and the displacement of the absorption pieces 13, 14 can be coupled, so that when an adjustment device is operated (not shown), the variation and the displacement are performed, the absorption pieces 13, 14 restricting the radiation beam 8 to the examination zone 11 for a preselected first intensity I_{01}, whilst the absorption pieces 13, 14 are moved out of the path of the radiation beam for the preselected second intensity I_{02}, after which the total positioning zone 4 is irradiated.

The restriction of the fan-shaped radiation beam 8 to the width of the examination zone 11 during the first measurement cycle, however, can also be realized in a manner other than by displacement of the absorption pieces 13, 14. For example, in the absence of a diaphragm device 12, the radiation source 1 and the row of detectors D can be shifted in the direction of the central ray 21 so that the extreme rays 9, 10 of the fan-shaped radiation beam 8 are brought to be tangential to the examination zone 11, as will be further described hereinafter.

Fig. 1a diagrammatically shows a further embodiment of a computed tomography apparatus for determining first and second measurement values during a first and a second measurement cycle. The apparatus shown comprises an X-ray source 1 which emits an X-ray beam 8 having a fixed semi-angle of fan α. The parts of the tomography apparatus which correspond to Fig. 1 are denoted by the same reference numerals or letters. The X-ray source 1 and the detector row D are movably mounted at a fixed distance from each other on a frame 50. The frame 50 is coupled on both sides, *via* a rack and pinion 51, to two electric motors 52 whereby the frame 50 with the X-ray source 1 and the detector row D can be displaced with respect to the system axis 2. The frame 50 comprises an oval aperture 53 which leaves the positioning zone 4 completely exposed in all positions of the frame 50 with respect to the system axis 2. For the first measurement cycle, the frame 50 is moved to the position shown, so that the X-ray source 1 irradiates only the examination zone 11. The extreme rays 9, 10 of the X-ray beam 8 form the rays 11a, 11b (see Fig. 1) which are tangential to the examination zone 11. After completion of the first measurement cycle, the frame 50 is moved for the second measurement cycle to a position (denoted by broken lines and the reference numeral 50') in which the source 1' irradiates the entire positioning zone 4. The extreme rays 9 and 10 of the X-ray beam 8 are then tangential to the positioning zone 4. The reference numerals of the parts displaced (such as the frame 50) are provided with an accent in the position for the second measurement cycle.

The embodiment of the tomography apparatus shown in Fig. 1a offers a better resolution for the examination zone 11 than the tomography apparatus shown in Fig. 1. This is because the tomography apparatus shown in Fig. 1a utilizes all of the detectors in the detector row D for detecting radiation along measurement paths through the examination zone 11. In the apparatus shown in Fig. 1, however, only some of the detectors of the detector row D are used. When use is made of the apparatus shown in Fig. 1a, a reconstructed image of examination zone 11 can contain as many pixels as a reconstructed image of the entire positioning zone 4 made by means of the apparatus shown in Fig. 1.

The spacing of the measurement paths in the examination zone 11 is smaller during the first measurement cycle than the spacing of the measurement paths in the examination zone 11 during the second measurement cycle. For the processing of the measurement values associated with the measurement paths the spacing must be the same as will be described in detail hereinafter. Interpolation between the measurement values obtained during the second measurement cycle produces a new set of (artificial) derived measurement values which belong to notional measurement paths with a modified spacing (adapted to the spacing of the paths during the first measurement cycle).

It is to be noted that the apparatus shown in Fig. 1a is known *per se* from United States Patent Specification No. 4,134,020.

The processing of the values from the first and the second groups of measurement values $I_1(p,\vartheta)$ and $I_2(p,\vartheta)$, respectively, will be described with reference to the block diagram shown in Fig. 2. The first and the second measurement values $I_1(p,\vartheta)$ and $I_2(p,\vartheta)$, respectively, are applied, *via* a data line 22, to a first input of a logarithmic conversion device 23 by means of which the first absorption values $Q_1(p,\vartheta) = -\ln(I_1(p,\vartheta)/I_{01})$ and the second absorption values $Q_2(p,\vartheta) = -\ln(I_2(p,\vartheta)/I_{02})$ are formed. The primary first and second intensities I_{01} and I_{02}, being preselected and measured, for example, by calibration measurements by means of the detectors 18, are stored for this purpose in a first memory 24, a second input being connected to the logarithmic conversion device 23. The device 23 comprises, for example, a divider circuit whose output is connected to a read-only memory in which a logarithmic conversion table is stored. On the basis of the position of the centre of the examination zone 11 and the measurement direction ϑ the arithmetic unit 25 calculates the coordinates of the extreme rays 11a and 11b which are tangential to the examination zone 11, and hence the positions p' of the two associated detector

elements 18. This calculation is predetermined by the geometry of the device and has to be performed only if the examination zone 11 is eccentrically situated with respect to the system axis 2. If the centre of the examination zone coincides with the system axis 2, the positions p' are the same for all measurement directions ϑ.

The positions p' are applied to a second memory 26 in which the first absorption values $Q_1(p,\vartheta)$ and the second absorption values $Q2(p,\vartheta)$ are separately stored. The positions p' are applied to the device 23 for logarithmic conversion, so that the first absorption values $Q_1(p,\vartheta)$ associated with measurement paths extending through the examination zone 11 are determined. During the measurement of the first measurement values, a control unit 27 is controlled by the positions p' determined in the arithmetic unit 25 which are dependent on the angle ϑ in the case of an accentrically situated examination zone 11. The control unit 27 drives, for example, an electric motor which realizes the displacement of the absorption pieces 13, 14 for the stopping down of the fan-shaped radiation beam 8 during the determination of the first measurement value $I_1(p,\vartheta)$.

From the first absorption values $Q_1(p,\vartheta)$ and the second absorption values $Q_2(p,\vartheta)$ approximated second absorption values $Q'_2(p,\vartheta)$ are determined by means of an electronic unit 28 (to be described in detail hereinafter) for the measurement paths extending outside the examination zone 11, said approximated second absorption values being used, together with the first absorption values $Q_1(p,\vartheta)$, to determine the absorption distribution $\mu(x, y)$ of the irradiated body slice by means of a known central computer 29. The absorption distribution $\mu(x, y)$ obtained is stored in a memory 31 and can be displayed, for example, on a monitor 30. The positions p' which indicate the position of the extreme rays 11a and 11b tangential to the examination zone 11 are applied to the unit 28 *via* the data line 32. *Via* the data line 33, the first and the second absorption values $Q_1(p,\vartheta)$ and $Q_2(p,\vartheta)$, respectively, are applied to the electronic unit 28, whilst *via* the data line 34 the approximated second absorption values $Q'_2(p,\vartheta)$ are returned from the electronic unit 28 to the memory 26, the absorption values $Q_2(p,\vartheta)$ then being replaced by the approximated absorption values $Q'_2(p,\vartheta)$.

Fig. 3 is a block schematic circuit of the electronic unit 28 for determining the approximated second absorption values $Q'_2(p,\vartheta)$. It is assumed that a first and a second measurement cycle are performed for a body slice to be examined and that no movements of the body occur. It may then also be assumed that differences in the first and the second measurement values determined respectively along one and the same measurement path during the first and the second measurement cycle are caused mainly by different radiation energy spectrums used in the two successive measurement cycles. It is generally applicable that the primary intensity I_0 is dependent of the radiation energy E, so $I_0(E)$. Because the radiation absorption is also dependent on the energy $\mu(x, y) = \mu(x, y, E)$, the first and the second measurement values are also dependent on the energy:

$$I(p,\vartheta, E) = \int I_0(E) \exp\left(-\int \mu(x, y, E)ds\right) dE \qquad (1)$$

A reduction of the radiation intensity by changing the X-ray tube voltage (anode voltage) during the second measurement cycle is accompanied by a change in the radiation energy spectrum, so that after conversion in the device 23 the second absorption values $Q_2(p,\vartheta)$, having been determined along measurement paths through the examination zone 11, usually depart from the first absorption values $Q_1(p,\vartheta)$ determined along the same measurement path. The departure is at least approximately corrected by a correction factor $C(\vartheta)$ which is defined as follows:

$$C(\vartheta) = \frac{1}{K(\vartheta)}\sum_p Q_1(p,\vartheta)/Q_2(p,\vartheta) \qquad (2)$$

and which is dependent on the measurement direction ϑ. Therein, $K(\vartheta)$ indicates the number of measurement paths through the examination zone 11 in a direction ϑ. The sum covers all measurement paths associated with a measurement direction ϑ and extending through the examination zone 11.

When the intensity variation of the X-ray source 1 is realized by variation of the tube current whilst the tube voltage remains the same, the correction value will be $C(\vartheta) = 1$, because the radiation energy spectrum does not change, so that the first and the second measurement values are measured with the same kind of radiation. For the determination of the approximate second absorption values $Q'_2(p,\vartheta)$ whose associated measurement paths extend outside the examination zone 11, the second absorption values $Q_2(p,\vartheta)$, for measurement paths outside the examination zone 11, are multiplied by the correction factor $C(\vartheta)$, so that:

$$Q'_2(p,\vartheta) = (C(\vartheta) \,.\, Q_2(p,\vartheta) \qquad (3)$$

The divider/adder circuit 35 shown in Fig. 3 determines the quotient $Q_1(p,\vartheta)/Q_2(p,\vartheta)$ of the first and the second absorption value $Q_1(p,\vartheta)$ and $Q_2(p,\vartheta)$ entering *via* the data line 30 and measured along the same measurement path, for this measurement path and also sums the successively calculated quotients. The calculation is performed for all measurement paths extending through the examination zone 11 under the control of the position data p' entering *via* the third data line 32. A counter 36 determines the number $K(\vartheta)$ of measurement paths extending through the examination zone 11 in a measurement direction ϑ and applies the number $K(\vartheta)$ to a divider circuit 37 which determines the correction value $C(\vartheta)$ from the sum of the quotients and the number $K(\vartheta)$ (see formula 2). In a multiplier 38, the approximate second absorption values $Q'_2(p,\vartheta)$ for measurement paths extending outside the examination zone 11 are determined by multiplying the absorption value $Q_2(p,\vartheta)$ by $C(\vartheta)$ (see formula 3). The approximated absorption values $Q'_2(p,\vartheta)$ are applied to the memory 26 again *via* the data line 34 (Fig. 2). The second absorption values $Q_2(p,\vartheta)$ for measurement paths outside the examinations zone 11 are thus replaced by the approximated absorption values $Q'_2(p,\vartheta)$. Said operations are successively performed for each measurement direction ϑ. Subsequently, the absorption distribution $\mu(x, y)$ is determined in known manner by means of a known central computer 29 which utilizes the first absorption values $Q_1(p,\vartheta)$ together with the approximated second absorption values $Q'_2(p,\vartheta)$.

If the absorption has to be determined within a body volume, several (for example, 20) parallel and adjoining body sections of a zone (region) of the body can be irradiated. When use is made of a computed tomography apparatus as shown in Fig. 1 or Fig. 1a, the sections are successively irradiated. It is not necessary to irradiate that part of the positioning zone 4 which is situated outside the examination zone 11 for each section to be examined. In the case where only a few adjoining slices are examined, it is sufficient to irradiate only the central section during a first as well as during a second measurement cycle, as herein defined. Irradiation is confined to the width of the examination zone of each of the other sections during a succession of corresponding first measurement cycles. The measurement values relating to the surroundings of the examination zone 11, which are derived from said central section during the second measurement cycle, are then used for the reconstruction of an absorption image of the adjoining sections as though these measurement values had been measured in the section to be reconstructed. If the part of the body 6 situated outside the examination zone 11 is "continuous" (*i.e.* if it exhibits few absorption transients from one slice to another), there will be no significant errors in the reconstructed images.

Instead of the successive irradiation of the separate sections of the body, it is alternatively possible to irradiate the various sections of the body 6 simultaneously when use is made of the detector D' shown in Fig. 6a which replaces the detector D shown in Fig. 1. To achieve this, the detector *D'* comprises several rows of detectors R, each row R detecting the radiation which passes through the examination zone 11 in a corresponding section. The detector *D'* furthermore comprises one long detector row R' which detects in one section the radiation passing through both the examination zone 11 and radiation passing through the part of the positioning zone 4 which is situated to either side of the examination zone 11. During the first measurement cycle, the ends 54 are shielded from radiation by means of a known, adjustable diaphragm which is arranged between the source 1 and the body 6. After the first measurement cycle, the diaphragm is adjusted so that all detector rows R are shielded from radiation.

If a substantial part of the body 6 is to be examined, so that a significant number of adjoining slices have to be irradiated (for example, from 10 to 20 slices), it is useful to determine measurement values in the part situated outside the examination zone in two or more sections instead of only one section during a second cycle. These sections should then be more or less uniformly distributed among all sections. By interpolation or extrapolation between the measurement values from the second measurement cycle notional or derived measurement values can thus be calculated for those slices for which no measurement values have been determined during the second measurement cycle. In addition to the successive irradiation of the adjoining sections by means of the device shown in the Figure, the detector *D''* shown in Fig. 6b also enables the irradiation of different sections during both a first and a second measurement cycle. To achieve this, the detector D'' comprises two long detector rows R' for the measurement of radiation which passes through sections throughout the entire positioning zone 4, and detector rows R for measuring radiation which only spans the examination zone 11.

It is assumed that the detector *D* shown in Fig. 6b comprises twenty detector rows in total, only the first and the last detector row R' thereof measuring radiation which passes to either side of the examination zone 11.

The second absorption values of the first and the last (for example, the twentieth) body section determined are denoted as $Q_2^{(1)}(p,\vartheta)$ and $Q_2^{(20)}(p,\vartheta)$. The first, and the last body section and the further body sections situated therebetween are irradiated during a first measurement cycle in order to obtain the first absorption values $Q_1^{(n)}(p,\vartheta)(1 \leq n \leq 20)$. The letter *n* denotes the number of a body section.

It is assumed hereinafter that the position and the size of the examination zones in the adjacent body sections are the same for each body section. If the position and the size of the examination zones are different, the various formulae will have to be changed accordingly. However, this does not affect the basic idea of the invention.

Using the method of determining the absorption distribution $\mu(x, y)$ within a body section as described with reference to Fig. 3, the approximated second absorption values $Q_2^{(n)}(p,\vartheta)$ are determined only for the first and the twentieth body section. Absorption values to be determined along measurement paths which are situated outside an examination zone in an n^{th} body slice between the first and the twentieth body section are determined by means of the second absorption values $Q_2^{(1)}(p,\vartheta)$ or by means of the second absorption values $Q_2^{(20)}(p,\vartheta)$ or by interpolation between these two absorption values.

An embodiment for determining the approximated second absorption values $Q'^{(n)}_2(p,\vartheta)$ for an n^{th} body section is described by the following equation 4 and 5:

$$Q'^{(n)}_2(p,\vartheta) = C(\vartheta)^{(n)} \cdot Q_2^{(1)}(p,\vartheta) \text{ for } n = 2, 3, \ldots 19 \qquad (4)$$

where

$$C(\vartheta)^{(n)} = \frac{1}{K(\vartheta)} \sum_p Q_1^{(n)}(p,\vartheta)/Q_2^{(1)}(p,\vartheta) \qquad (5)$$

The quotient $Q_1^{(n)}(p,\vartheta)/Q_2^{(1)}(p,\vartheta)$ is formed from the first absorption values $Q_1^{(n)}(p,\vartheta)$ of the relevant body layer *n* and from the second absorption values $Q_2^{(1)}(p,\vartheta)$ of the first body section along measurement paths extending through the examination zone in the body slice *n* in the measurement direction ϑ. The sum of all quotients associated with the measurement direction ϑ is divided by the number $K(\vartheta)$ which indicates the number of measurement paths extending through the examination zone of the relevant body slice for a measurement direction.

The second absorption values $Q_2(p,\vartheta)$ of the first body layer are multiplied (see formule 4) by the correction factor $C(\vartheta)^{(n)}$ for each direction ϑ in order to determine approximated second absorption values $Q'^{(n)}_2(p,\vartheta)$ for the n^{th} body section associated with the measurement paths extending outside the examination zone.

This method, where each time the first absorption value $Q_2^{(1)}(p,\vartheta)$ of the first body slice is used in order to obtain the absorption distribution of an n^{th} body section, however, produces only an approximate absorption distribution in the successive n^{th} body sections. The results may be displayed, for example, as a provisional analysis on the monitor 30 (Fig. 2).

However, when all measurement values are available, so that the first and the last (the twentieth) body secton have been irradiated during a first and a second measurement cycle, whilst the intermediate body sections have been irradiated only during a first measurement cycle for the determination of first absorption values $Q_1^{(n)}(p,\vartheta)$, the second absorption values $Q_2^{(20)}(p,\vartheta)$ can be used for determining second absorption values in the intermediate body sections. An approximated second absorption value $Q'^{(n)}(p,\vartheta)$ for a measurement path in an n^{th} body section is then determined, for example, by:

$$Q'^{(n)}_2(p,\vartheta) = \bar{C}(\vartheta)^{(n)}\{Q_2^{(1)}(p,\vartheta) \cdot a^{(n)} + Q_2^{(20)}(p,\vartheta) \cdot b^{(n)}\} \qquad (6)$$

in which $a^{(n)}$ and $b^{(n)}$ are interpolation factors which are, for example, equal to:

$$a^{(n)} = \frac{20 - n}{20} \qquad (7)$$

and

$$b^{(n)} = 1 - a^{(n)}, \qquad (8)$$

and wherein:

$$\bar{C}(\vartheta)^{(n)} = \frac{1}{K(\vartheta)} \sum_p Q_1^{(n)}(p,\vartheta)/\{Q_2^{(1)}(p,\vartheta)a^{(n)} + Q_2^{(20)}(p,\vartheta)\, b^{(n)}\} \qquad (9)$$

The correction factor $\bar{C}(\vartheta)^{(n)}$ depends on the second absorption values in the first and the twentieth body section. Thus, for an $(n)^{th}$ body slice approximated second absorption values $Q'^{(n)}_2(p,\vartheta)$ are obtained for measurement paths outside the examination zone in the n^{th} slice.

Fig. 4 shows a block diagram of a circuit 28' for executing the described methods. The circuit 28' comprises a memory 39 in which all first absorption values $Q_1^{(1)}(p,\vartheta), \ldots, Q_1^{(n)}(p,\vartheta), \ldots, Q_1^{(20)}(p,\vartheta)$ and the second absorption values $Q_2^{(1)}(p,\vartheta)$, $Q_2^{(20)}(p,\vartheta)$ measured in the first and the twentieth body slice are stored.

The interpolation factors $a^{(n)}$ and $b^{(n)}$ are stored in a memory 40. After completion of all measurement cycles for the irradiation of the 20 body sections, the multiplier and adder circuit 41 successively performs two multiplications for each p value for each measurement direction and for each section (see formule 6): $Q_2^{(1)}(p,\vartheta)a^{(n)}$ and $Q_2^{(20)}(p,\vartheta)b^{(n)}$. For each body section 2, 3, ... 19, the sum of both multiplications is stored in the memory 39, whilst the number $K(\vartheta)$ counted by the counter 36 is stored in a memory 42 for each measurement direction ϑ and each layer n after the calculations for a measurement direction. The elements denoted by the reference numerals 35, 36, 37, 38 correspond to the elements in Fig. 3 which are denoted by the sane reference numerals. The first absorption values $Q_1^{(n)}(p,\vartheta)$ stored in the memory 39 are returned, together with the approximated second absorption values $Q'^{(n)}_2(p,\vartheta)$, *via* the data lines 43 and 34, to the second memory 26 (see Fig. 2), so that they are available for determining the absorption distribution in the various body sections.

For the determination of the absorption distribution in a three-dimensional part of the body 1 it is also possible to irradiate the entire positioning zone of the first and the twentieth body section in only one measurement cycle and the first intensity I_{01} in order to determine first absorption values $\bar{Q}_1^{(1)}(p,\vartheta)$ for the first body slice and $\bar{Q}_1^{(20)}(p,\vartheta)$ for the twentieth body slice, respectively. The approximated second absorption values $Q'^{(n)}_2(p,\vartheta)$ for an intermediate body slice n are then determined as follows:

$$Q'^{(n)}_2(p,\vartheta) = \bar{Q}_1^{(1)}(p,\vartheta).\ a^{(n)} + \bar{Q}_1^{(20)}(p,\vartheta)b^{(n)} \qquad (10)$$

in which $a^{(n)}$ and $b^{(n)}$ are determined by the formulae (7) and (8). The measurement paths associated with the various absorption values occupy approximately the same position with respect to the system axis 2 in said body sections. The absorption distribution $\mu(x, y)$ of the body section (n) is reconstructed by means of the approximated absorption values $Q'^{(n)}_2(p,\vartheta)$ and the first absorption values $Q_1^{(n)}(p,\vartheta)$ whose associated measurement paths extend through the examination zone of the intermediate body slice n. Because only one measurement cycle is performed for the first and twentieth body slice, the overall measurement time is thus further reduced.

It will be clear that particularly the detectors shown in the Figs. 6a and b can be used for the described method. The overall measurement time required for all n different sections is then reduced to the measurement time required for a single section. This is notably important because the body 6 must be in rest during the measurement. Artefacts in the images to be reconstructed can be reduced or prevented by the reduction of the measurement time because, for example, holding the breath is quite feasible for 4 to 6 seconds (measurement time for section), but a measurement time of from 40 to 60 seconds (ten sections) would already give rise to problems.

The reconstruction methods customarily used thus far do not take into account the fact that the correction of the second absorption values $Q_2^{(n)}(p,\vartheta)$ by multiplication by the correction factor $C(\vartheta)$, $\bar{C}^{(n)}(\vartheta)$ forms only an approximation of the first absorption values $Q_1^{(n)}(p,\vartheta)$. Local discrepancies cannot be eliminated thereby. Local discrepancies of this kind, however, occur, for example, between first absorption values $Q_1(p',\vartheta)$ and approximated second absorption values $Q'_2(p',\vartheta)$, where p' is the position or the path of an extreme ray which is tangential to the examination zone 11. Due to the step-wise transients between $Q_1(p',\vartheta)$ and $Q'_2(p',\vartheta)$ local artefacts may occur in the reconstructed absorption distribution.

In order to avoid this, a local adaptation of the approximated second absorption values $Q'_2(p',\vartheta)$ to the first absorption values $Q_1(p',\vartheta)$ is realized for each examination zone and for each measurment direction μ by a more elaborate correction.

The more elaborate correction is executed in accordance with the formula

$$Q''^{(n)}_2(p,\vartheta) = d^{(n)}(p,\vartheta).Q'^{(n)}_2(p,\vartheta); \text{ where } n = 1, 2, \ldots 20 \qquad (11)$$

Therein, the absorption values $Q'^{(n)}_2(p,\vartheta)$ are the approximated second absorption values already calculated by the arithmetic unit 38 (see Fig. 3). The absorption value $Q''^{(n)}_2(p,\vartheta)$ is the corrected approximated second absorption value associated with a measurement path outside an examination zone 11. The factor $d^{(n)}(p,\vartheta)$ is a second correction factor which realizes a monotonously decreasing transition from the first absorption values $Q_1{}^{(n)}(p,\vartheta)$ in position $p < p'$ to the approximated second absorption value $Q'^{(n)}_2(p,\vartheta)$ in the position $p > p'$, the second correction factor satisfying, for example:

$$d^{(n)}(p,\vartheta) = 1 - f(p-p') + \frac{Q_1^{(n)}(p',\vartheta)}{Q'^{(n)}_2(p',\vartheta)} \cdot f(p-p') \qquad (12)$$

Therein, $f(p-p')$ is a weighting function which monotously decreases as a function of distance, where $f(p-p')=1$ for $p-p'=0$ and $f(p-p')<1$ for $|p-p'|$ 0. The limitation of the more elaborate correction to a local range of the absorption values is obtained by a suitable choice of a weighting factor $f(p-p')$.

The elements denoted by the reference numerals 35 to 42 in Fig. 4 correspond to the elements bearing these reference numerals in Fig. 5. As appears from Fig. 5, the approximated second absorption values $Q'^{(n)}_2(p,\vartheta)$ obtained by means of the multiplier 38 are applied, *via* a data line 48, to the memory 39 in order to replace the absorption sums $Q_2^{(1)}(p,\vartheta)a^{(n)} + Q_2^{(20)}(p,\vartheta)b^{(n)}$ stored therein. In the divider 44 the quotients $Q_1^{(n)}(p',\vartheta)/Q'^{(n)}_2(p',\vartheta)$ (see formule 12) are formed and from a memory (for example, a read-only memory) the weighting factors $f(p-p')$ are retrieved, after which the second correction factor $d^{(n)}(p,\vartheta)$ is determined by means of the multiplier/adder 46. The second correction (see formule 11) is subsequently performed in the multiplier 47 to which, therefore, the second correction factor $d^{(n)}(p,\vartheta)$ and the second approximated absorption value $Q_2^{(n)}(p,\vartheta)$ are applied from the memory 39.

The method illustrated by the block diagram of Fig. 5 is also suitable for adequate correction of deviations between first absorption values $Q_1^{(n)}(p,\vartheta)$ and second absorption values $Q_2^{(n)}(p,\vartheta)$ caused by patient movements. The more elaborate corrected approximated second absorption vale $Q''^{(n)}_2(p,\vartheta)$ is introduced into the memory 26 *via* data line 34.

The method in accordance with the invention is not restricted to use in computer tomography apparatus comprising a detector device which moves with the source as shown in Fig. 1, but can also be used in computer tomography apparatus comprising a single detector or some tens of detectors or a stationary detector device which comprises a closed ring of detectors.

The method claimed herein relates to a method of determining the distribution of radiation absorption in a flat examination zone in a body, but use of the method as a method of diagnosis practiced on the human or animal body is hereby specifically excluded from the scope of the method claimed. However, no such restriction is to be implied concerning the scope of the apparatus claimed herein.

CLAIMS

1. A method of determining the distribution of radiation absorption in a flat examination zone in a body which is situated within a positioning zone which completely encloses the examination zone, the examination zone being completely irradiated in different measuring directions which are situated within the examination zone along a large number of measuring paths by means of radiation of a first intensity in order to determine first measurement values, the part of the positioning zone which is situated outside the examination zone being irradiated in a corresponding number of measuring paths by means of radiation of a second intensity which is lower than the first intensity in order to determine second measurement values, first absorption values being determined from the first measurement values and second absorption values being determined from the second measurement values, said absorption values being used for the reconstruction of the distribution of the radiation absorption, characterized in that during a first measuring cycle only the examination zone (11) of the body slice to be examined is irradiated with the first intensity (I_{01}) in order to determine the first absorption values ($Q_1(p,\vartheta)$), whilst during a second measuring cycle the total positioning zone (4) of the same or a neighbouring body slice is irradiated with the second intensity (I_{02}) in order to determine second absorption values ($Q_2(p,\vartheta)$).

2. A method as claimed in Claim 1, characterized in that the body (6) is displaced in a direction transversely of all measuring directions in order to irradiate body slices which are situated in parallel to and adjacent at least one already irradiated body slice (n), after which only an examination zone in the body slice (n) to be examined is irradiated with radiation of the first intensity I_{01}) in order to determine first absorption values ($Q_1^{(n)}(p,\vartheta)$, the second absorption values of the already irradiated body slice, whose associated measuring paths extend outside the examination zone (11) being used for each measuring direction as approximated second absorption values ($Q'^{(n)}_2(p,\vartheta)$ for the reconstruction of the radiation absorption distribution in the body slice (n).

3. A method as claimed in Claim 1 or 2, characterized in that the second intensity (I_{02}) which is lower than the first intensity (I_{01}) is adjusted by reduction of the tube current of an X-ray source (1).

4. A method as claimed in Claim 1 or 2, characterized in that the second intensity (I_{02}) is adjusted by reduction of the tube voltage of an X-ray source (1).

5. A method as claimed in the Claims 1 and 4, characterized in that for each measuring

direction there is formed a correction factor ($C(\vartheta)$) whereby the second absorption values whose associated measuring paths extend outside the examination zone are multiplied in order to form approximated second absorption values ($Q'_2(p,\vartheta)$, the correction factor being determined by dividing all first absorption values which are associated with one measuring direction (ϑ) and with measuring paths extending through the examination zone (11) by the second absorption value associated with the same measuring path, after which all quotients are mathematically averaged in order to determine the correction factor.

6. A method as claimed in the Claims 2 and 4, characterized in that for each further body slice (n) and each measuring direction (ϑ) a further correction value ($C^{(n)}(\vartheta)$) is formed by determining a quotient of each further first absorption value ($Q_1^{(n)}(p,\vartheta)$) and a second absorption value ($Q_2^{(1)}(p,\vartheta)$) of the first body slice determined along the same measuring path, and by arithmetically averaging all quotients determined for the measuring direction (ϑ), the second absorption values ($Q_2^{(1)}(p,\vartheta)$) of the first body slice whose associated measuring paths extend in this measuring direction (ϑ) outside the examination zone (11) being multiplied by the further correction value ($C^{(n)}(\vartheta)$) in order to determine approximated second absorption values ($Q'^{(n)}_2(p,\vartheta)$).

7. A method as claimed in the Claims 2, 3 or 4, characterized in that for the determination of a radiation absorption distribution in a three-dimensional body zone the total positioning zone of a first and a last body slice, bounding the body zone is irradiated with the second intensity (I_{o2}) in order to determine second absorption values ($Q_2^{(1)}(p,\vartheta)$, $Q_2^{(N)}(p,\vartheta)$), the approximated further second absorption values ($Q'^{(n)}_2(p,\vartheta)$) for a body slice (n) which is situated between the first and the last body slice 1 and (N), respectively, being determined by forming for each measuring path in the further body slice (n) an absorption sum ($Q_2^{(n)}(p,\vartheta)$) which is composed of a multiplication of a second absorption value ($Q_2^{(1)}(p,\vartheta)$) whose associated measuring path extends within the first body slice (1), by a first weighting factor ($a^{(n)}$), and of a multiplication of a second absorption value ($Q_2^{(N)}(p,\vartheta)$) whose associated measuring path extends within the last body slice (N) by a second weighting factor ($b^{(n)}$), said meauring paths all having the same orientation (p,ϑ) within the three parallel extending examination planes (1, n, N), the weighting factors whose sum equals one being dependent on the distance between the further body slice (n) and the first (1) and the last (N) body slice, respectively, the absorption sums ($Q_2^{(n)}(p,\vartheta)$ which are associated with the measuring paths extending within the examination zone of the further body slice (n) and the further first absorption values ($Q_1^{(n)}(p,\vartheta)$ being used to determine an approximated correction factor ($\bar{C}^{(n)}(\vartheta)$) by determining the quotient of a further first absorption value ($Q_1^{(n)}(p,\vartheta)$) and an absorption sum ($Q_2^{(n)}(p,\vartheta)$) of the same body slice (n) associated with the same measuring path, all quotients formed for the measuring direction (ϑ) being subsequently arithmetically averaged in order to determine the approximated correction factor ($\bar{C}^{(n)}(\vartheta)$), after which in order to determine approximated further second absorption values ($Q'^{(n)}_2(p,\vartheta)$), each absorption sum ($Q_2^{(n)}(p,\vartheta)$) is multiplied by the correction factor ($\bar{C}^{(n)}(\vartheta)$), the measuring paths associated with said absorption sums extending outside the examination zone of the further body slice (n).

8. A method as claimed in Claim 7, characterized in that the first weighting factor is chosen as

$$a^{(n)} = \frac{N-n}{N}$$

and the second weighting factor as $b^{(n)} = 1 - a^{(n)}$, n being the number of body slices from the first body slice and N being the total number of irradiated body slices.

9. A method as claimed in any of the Claims 5, 6 or 7, characterized in that in order to reduce local image artefacts, for each body slice (n) the approximated second absorption values ($Q_2^{(n)}(p,\vartheta)$ or the approximated further second absorption values ($Q'^{(n)}_2(p,\vartheta)$) are multiplied by a further weighting factor ($d^{(n)}$) which is dependent on the difference in location ($p-p'$) between the measuring paths (p), extending in parallel with respect to each other in the measuring direction (ϑ), and the measuring path (p') which is tangent to the examination zone of the body slice (n).

10. A method as claimed in Claim 9, characterized in that the further weighting factor is chosen as

$$d^{(n)}(p,\vartheta) = 1 - f(p-p') + \frac{Q_1^{(n)}(p',\vartheta)}{Q'^{(n)}_2(p',\vartheta)} f\,(p-p'),$$

in which $Q_1^{(n)}(p,\vartheta)$ is a first absorption value and $Q'^{(n)}_2(p,\vartheta)$ is an approximated second absorption value of a first body slice and a further (n) body slice, respectively, along the measuring paths

(p') which are tangent to the examination zone, f(p−p') being a monotously decreasing weighting function.

11. A method as claimed in Claim 1, characterized in that during the first and the second measuring cycle a source for generating the penetrating radiation is situated at a first and a second distance, respectively, from the examination zone, the first distance being smaller than the second distance.

12. A computer tomography apparatus for determining the radiation absorption distribution in a slice of a body, comprising a radiation source for generating a beam of penetrating radiation in order to irradiate a body in a plurality of directions which are situated in one plane, a detector device for measuring the radiation having passed through the body in order to supply absorption values which are a measure for the radiation attenuation along measuring paths which pass through the body and which are situated in one plane, a support on which the radiation source and the detector device are mounted one opposite the other, a positioning zone for the body to be examined being situated therebetween, a central processing device for determining absorption coefficients of the radiation absorption distribution from the absorption values, a memory for storing the absorption values and the absorption coefficients, and a display device for the display of the radiation absorption distribution, characterized in that the detector device comprises at least one short and one long detector row which are arranged parallel to each other, the detectors which are situated at the ends of the long detector row detecting radiation which is tangent to the positioning zone, whilst the short detector row determines the size of an examination zone which is situated within the positioning zone.

13. A computer tomography apparatus as claimed in Claim 12, characterized in that the detector device comprises two long detector rows wherebetween short detector rows are situated.

14. A computer tomography apparatus for determining the radiation absorption distribution in a slice of a body, comprising a radiation source for generating a beam of penetrating radiation in order to irradiate a body in a plurality of directions which are situated in one plane, a detector device for measuring the radiation having passed through the body in order to supply absorption values which are a measure for the radiation attenuation along measuring paths which pass through the body and which are situated in one plane, a support on which the radiation source and the detector device are mounted one opposite the other, a positioning zone for the body to be examined being situated therebetween, a central processing device for determining absorption coefficients of the radiation absorption distribution from the absorption values, a memory for storing the absorption values and the absorption coefficients, and a display device for the display of the radiation absorption distribution, characterized in that there is provided a power supply unit for operating the radiation source with two different radiation intensities in order to determine first absorption values ($Q_1(p,\vartheta)$) associated with measuring paths extending through an examination zone, covering a central part of the positioning zone, during a first measuring cycle for each of said directions by means of a high radiation intensity (I_{01}), and for determining second absorption values ($Q_2(p,\vartheta)$) associated with measuring paths which cover the entire positioning zone during a second measuring cycle for each of said directions with a low radiation intensity (I_{02}), the apparatus comprising further arithmetic means for determining the number (K) of measuring paths which extend through the examination zone per direction, for determining and summing quotients of the first and second absorption values $Q_1(p,\vartheta)$ and $Q_2(p,\vartheta)$ associated with said measuring paths, for dividing the sum thus obtained by the number (K) of measuring paths, thus determining a correction factor $C(\vartheta)$ according to the formule

$$C(\vartheta) = ((\Sigma(Q_1(p,\vartheta)/Q_2(p,\vartheta))K,$$

and for multiplying the further second absorption values ($Q_2(p,\vartheta)$) which are associated with said measuring direction and which have been determined along measuring paths which extend outside the examination zone by the correction factor $C(\vartheta)$.

15. A computer tomography apparatus as claimed in the Claim 13 or the Claims 13 and 14, characterized in that the apparatus comprises an interpolation circuit for determining interpolated values from the absorption values supplied by the long detector rows.

16. A method of determining the distribution of radiation absorption in a flat sectional examination zone in a body which is situated within a positioning zone which completely surrounds the examination zone, the examination zone being completely irradiated in different measurement directions which are situated within the examination zone along a large plurality of measurement paths by means of radiation of a first intensity in order to derive a first group of measurement values, the part of the positioning zone which is situated outside the examination zone being irradiated in a corresponding plurality of measurement directions along measurement paths by means of radiation of a second intensity which is lower than the first intensity in order to derive a second group of measurement values, a first group of absorption values being determined from the first group of measurement values and a second group of absorption values

being determined from the second group of measurement values, said absorption values being used for the computed reconstruction of the distribution of the radiation absorption, characterized in that during a first measurement cycle, as herein defined, the irradiated width of the body section only spans the examination zone of the body section under examination, and is irradiated with radiation having the first intensity (I_{01}) in order to determine the first group of absorption values ($Q_1(p,\vartheta)$), and during a second measurement cycle, as herein defined, the entire positioning zone of the same or of an adjacent body section is irradiated with radiation having the second intensity (I_{02}) in order to determine the second group of absorption values ($Q_2(p,\vartheta)$).

17. A method as claimed in Claim 16, characterized in that the body is displaced in a direction at right angles to all the measurement directions in order successively to irradiate body sections which are situated parallel to and adjacent an initially irradiated body section (n), the irradiated width of the body section only extending so as to span an examinaton zone in each successive body section (n) under examination when irradiated with radiation of the first intensity (I_{01} in order to determine respective corresponding first groups of absorption values ($Q_1^{(n)}(p,\vartheta)$, respective absorption values of the second group determined for the initially irradiated body section, whose associated measurement paths extend outside the examination zone, being used for each corresponding measurement direction as approximate second absorption values ($Q'^{(n)}_2(p,\vartheta)$ for the computed reconstruction of the radiation absorption distribution in each successive body slice (n).

18. A method as claimed in Claim 16 or 17, characterized in that the second intensity (I_{02}) which is lower than the first intensity (I_{01}), is provided by reducing the tube current of an X-ray source.

19. A method as claimed in Claim 16 or 17, characterized in that the second intensity (I_{02}) is provided by reducing the tube voltage of an X-ray source.

20. A method as claimed in any one of Claims 16 to 19, characterized in that for each measurement direction there is formed a correction factor ($C(\vartheta)$) by which the second absorption values whose associated measurement paths extend outside the examination zone, are multiplied in order to form approximate second absorption values ($Q'_2(p,\vartheta)$, the correction factor being determined by dividing each first absorption value associated with one measurement direction (ϑ) and with respective measurement paths extending through the examination zone, by the second absorption value associated with the same measurement path, after which all quotients are mathematically averaged in order to determine the correction factor.

21. A method as claimed in Claim 20 when dependent on claim 17, or on claim 18 or claim 19 when dependent on claim 17, characterized in that for each further body section (n) and each measurement direction (ϑ) a further correction value ($C^{(n)}(\vartheta)$) is formed by determining a quotient of each absorption value ($Q_1{}^{(n)}(p,\vartheta)$) or the corresponding first groups of absorption values, and that absorption value ($Q_2^{(1)}(p,\vartheta)$) of the second group of absorption values relating to the initially irradiated body slice, and determined along the same measurement path, and arithmetically averaging all the quotients determined for that measurement direction (ϑ), the absorption values ($Q_2^{(1)}(p,\vartheta)$) of the second group of absorption values relating to the initial irradiated body slice, and which are determined using measurement paths extending in said measurement direction (ϑ) outside the examination zone, being multiplied by the further correction value ($C^{(n)}(\vartheta)$) in order to determine the respective approximate absorption values ($Q'^{(n)}_2(p,\vartheta)$) of the second group of absorption values relating to said further body section.

22. A method as claimed in any one of Claims 17, 18 and 19, characterized in that for the determination of a radiation absorption distribution in a three-dimensional body zone the entire positioning zone relating to a first and a last body section, bounding the body zone, is irradiated with the second intensity (I_{02}) in order to determine absorption values ($Q_2^{(1)}(p,\vartheta)$, $Q_2^{(N)}(p,\vartheta)$, of corresponding second groups of absorption values, the approximate absorption values ($Q'^{(n)}_2(p,\vartheta)$ of the second group of absorption values relating to a further body section (n) which is situated between the first and the last body section 1 and (N), respectively, being determined by forming for each measurement path in the further body section (n) an absorption sum ($Q_2^{(n)}(p,\vartheta)$) which is formed by summing the product of an absorption value ($Q_2^{(1)}(p,\vartheta)$) of a said second group, whose associated measurement path extends within the first body section (1), and a first weighting factor ($a^{(n)}$), and the product of an absorption value ($Q_2^{(N)}(p,\vartheta)$) of a said second group, whose associated measurement path extends within the last body section (N), and a second weighting factor ($b^{(n)}$), said measurement paths all having the same orientation (p,ϑ) within the three parallel extending examination planes (1, n, N), the first and second weighting factors whose sum equals unity, being dependent on the distance between the further body section (n) and the first (1) and the last (N) body section, respectively, the absorption sums ($Q_2^{(n)}(p,\vartheta)$ which are associated with the measurement paths extending within the examination zone of the further body section (n) and the absorption values ($Q_1^{(n)}(p,\vartheta)$ of the first group of absorption values relating to said further body section, being used to determine an approximate correction factor ($\bar{C}^{(n)}(\vartheta)$) by determining the quotient of an absorption value ($Q_1^{(n)}(p,\vartheta)$) from the first group of absorption values relating to the further body section, and an absorption sum ($Q_2^{(n)}(p,\vartheta)$) of the

same body section (n) associated with the same measurement path, all quotients formed for the measurement direction (ϑ) being subsequently arithmetically averaged in order to determine the approximate correction factor ($\bar{C}^{(n)}(\vartheta)$), after which in order to determine the respective approximate absorption values ($Q'^{(n)}_2(p,\vartheta)$ of the second group of absorption values relating to the further body section, each absorption sum ($Q^{(n)}_2(p,\vartheta)$) is multiplied by the correction factor ($\bar{C}^{(n)}(\vartheta)$), the measurement paths associated with said absorption sums extending outside the examination zone of the further body section (n).

23. A method as claimed in Claim 22, characterized in that the first weighting factor is chosen as

$$a^{(n)} = \frac{N-n}{N}$$

and the second weighting factor as $b^{(n)} = 1 - a^{(n)}$, n being the number of body sections from the first body section and N being the total number of successively irradiated body sections.

24. A method as claimed in any one of Claims 20, 21 and 22, characterized in that in order to reduce local image artefacts, for each body section (n) the approximate second absorption values ($Q^{(n)}_2(p,\vartheta)$) or the approximated further second absorption values ($Q'^{(n)}_2(p,\vartheta)$) are multiplied by a further weighting factor ($d^{(n)}$) which is dependent on the difference in location (p−p') between the measurement paths (p), extending in parallel with respect to each other in the measurement direction (ϑ), and the measurement path (p') which is tangential to the examination zone in the body section (n).

25. A method as claimed in Claim 24, characterized in that the further weighting factor is chosen as

$$d^{(n)}(p,\vartheta) = 1 - f(p-p') + \frac{Q_1^{(n)}(p',\vartheta)}{Q'^{(n)}_2(p',\vartheta)} f\,(p-p'),$$

in which $Q_1^{(n)}(p,\vartheta)$ is a first absorption value and $Q'^{(n)}_2(p,\vartheta)$ is an approximated second absorption value of a first body section and a further (n) body section, respectively, along the measurement paths (p') which are tangential to the examination zone, f(p−p') being a monotously decreasing weighting function.

26. A method as claimed in Claim 16, characterized in that during the first and the second measurement cycle a source for generating the penetrating radiation is situated at a first and a second distance, respectively, from the examination zone, the first distance being smaller than the second distance.

27. Computed tomography apparatus for determining the radiation absorption distribution in a planar section of a body, comprising a radiation source for generating a beam of penetrating radiation in order to irradiate a body in a plurality of directions which are situated in a common plane, a detector device for measuring the radiation after passing through the body in order to provide absorption values which are a measure of the radiation attenuation along measurement paths which pass through the body and which are situated in the common plane, a support on which the radiation source and the detector device are mounted one opposite the other, a positioning zone for the body to be examined being situated therebetween, a central processing device for determining local absorption coefficients of the radiation absorption distribution from the absorption values, a memory for storing the absorption values and the absorption coefficients, and a display device for the display of the radiation absorption distribution, characterised in that said apparatus includes control and adjustment means for defining and carrying out a respective first and second measurement cycle, as herein defined, and arranged during said first measurement cycle to cause the span of the irradiation beam to be confined to the width of an examination zone which lies within the planar section of a body under examination, the beam intensity at the body section to assume a first intensity (I_{01}) and to allocate absorption values formed from the output of the detector device to a first group of absorption values ($Q_1(p,\vartheta)$), and during said second measurement cycle to cause the irradiation beam to span the entire width of a positioning zone surrounding the examination zone, and within which the entire body section is accommodated, the beam intensity at the body section to assume a second intensity (I_{02} which is lower than said first intensity, and to allocate absorption values formed from the output of the detector device to a second group of absorption values ($Q_2(p,\vartheta)$).

28. Computed tomography apparatus as claimed in Claim 27 characterized in that the detector device comprises at least one short and one long detector row which are arranged parallel to each other, the detectors which are situated at the ends of the long detector row detecting radiation which is tangential to the positioning zone, whilst the short detector row

determines the size of the examination zone which is situated within the positioning zone.

29. Computed tomography apparatus as claimed in Claim 28, characterized in that the detector device comprises two long detector rows wherebetween short detector rows are situated.

30. Computed tomography apparatus as claimed in any one of Claims 27 to 29 characterized in that there is provided a power supply unit for operating the radiation source with two different radiation intensities in order to determine the first group of absorption values ($Q_1(p,\vartheta)$) associated with measurement paths extending through an examination zone extending over a central part of the positioning zone, during a first measurement cycle for each of said directions by means of a high radiation intensity (I_{01}), and for determining the second group of absorption values ($Q_2(p,\vartheta)$) associated with measurement paths which extend over the entire positioning zone during a second measurement cycle for each of said directions with a low radiation intensity (I_{02}), the apparatus comprising further arithmetic means for determining the number (K) of measurement paths which extend through the examination zone for each direction, for determining and summing quotients of respective absorption values $Q_1(p,\vartheta)$ and $Q_2(p,\vartheta)$ from said first and second groups of absorption values, and associated with common said measurement paths, for dividing the sum thus obtained by the number (K) of measurement paths, thus determining a correction factor $C(\vartheta)$ according to the formula

$$C(\vartheta) = ((\Sigma(Q_1(p,\vartheta)/Q_2(p,\vartheta))K,$$

and for multiplying absorption values ($Q_2(p,\vartheta)$) of the second groups of absorption values, which are associated with said measurement direction and which have been determined along measurement paths which extend outside the examination zone by the correction factor $C(\vartheta)$.

31. A computed tomography apparatus as claimed in the Claim 13 or the Claims 13 and 14, characterized in that the apparatus comprises an interpolation circuit for determining interpolated values from the absorption values supplied by the long detector rows.

32. A method of computed tomography, substantially as herein decribed with reference to the accompanying drawings.

33. Computed tomography apparatus, substantially as herein described with reference to the accompanying drawings.

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